THE TECHNOLOGIES OF IHI FLUE GAS DESULFURIZATION & SELECTIVE CATALYTIC REDUCTION SYSTEMS IN THE APEC REGION

Yasuto Nara
Air Pollution Control Design Department, Power Plant Division
Ishikawajima-Harima Heavy Industries Co., Ltd.
Japan

ABSTRACT

At present, environmental protection is very important all over the world. Ishikawajima-Harima Heavy Industries (IHI) Flue Gas Desulfurization (FGD) systems and Selective Catalytic Reduction (SCR) systems contribute to environmental protection in the APEC region. FGD and SCR systems are easily implemented in operating power plants. This paper presents our experience retrofitting power plants with FGD and SCR systems in the APEC region.

The HSINTA Unit 3 & 4 FGD system now under construction is introduced as one of the latest FGD systems for utility boilers in the APEC region. For industrial use, we also introduce a simplified (in-line type) FGD system delivered to Thai Union Paper Public Co., Ltd.

For removal of nitrogen oxides, IHI SCR systems can perfectly match flue gas characteristics with a suitable catalyst, and with a compact design can easily be accommodated when retrofitting existing plants.

1) INTRODUCTION

Given the large reserves, fossil fuel, especially coal, has an important position in energy supply for the APEC region, which is experiencing high-speed economic growth; however, use of fossil fuels exacerbates environmental pollution. Acid rain caused by SOx and NOx emissions, and air pollution caused by exhaust particulates, have become a serious problem in recent years. Environmental protection is, therefore, highly important to preserve human life and health.

Table 1 and Table 2 show the dramatic increase in SOx and NOx emissions in and near Asia. This increase was caused mainly by boilers constructed to meet rising demands for power. Now the most important task for us is to alleviate air pollution from coal-fired boilers in the region, a problem that can be solved most effectively with application of FGD and SCR systems, a growing market in the APEC region.

In the 1950s, air pollution was growing dramatically worse in Japan, but now, efforts by industrial, governmental and academic sectors have almost succeeded in suppressing the pollution. Environmental protection equipment is improved, and FGD and SCR systems especially have made remarkable progress. Manufacturing of environmental equipment also has shown remarkable growth. The historical records of FGD and SCR systems installed by year in Japan are shown in Figures 1 and 2.

2) FLUE GAS TREATMENT SYSTEM FLOW

A typical flue-gas-treatment system for coal-fired boilers is shown in Figure 3. The system consists of an SCR system (the NOx removal section), the Electrostatic Precipitator, and an FGD system.

The SCR system is located downstream of the boiler because flue-gas temperature at 300–400 C in this position is most suitable for achieving high De-NOx efficiency with catalyst. The FGD system, where both SOx and dust are removed, is located upstream of the stack, and cleaned flue gas is exhausted from the stack.

3) FGD SYSTEM PROCESS

There are various kinds of FGD systems classified into several processes based on kinds of absorbent and byproducts; the main FGD systems are shown in Table 3.

The cost of these processes is important to boiler plants. Capital and operating costs are shown in Figure 4; this shows cost for a design basis only, but in the case of commercial plants, capital and operating costs depend largely on site and operating conditions.

The operating cost for the limestone-gypsum process is less because the absorbent of limestone is less expensive than any other wet FGD process.

The limestone-gypsum process is the most widely commercialized in the world, not only because of cost effectiveness, but also because there are large limestone deposits worldwide; the byproduct, gypsum, has various uses, such as plaster board and cement additives, and the high reliability of the process is confirmed worldwide. The limestone-gypsum process is shown in Figure 5. Features of this process are as follows.

< Chemical Reaction >

Desulfurization:	$SO_2 + H_2O =$	H_2SO_3
Oxidization:	$H_2SO_3 + 1/2\ O_2 =$	H_2SO_4
Neutralization:	$H_2SO_4 + CaCO_3 + H_2O =$	$CaSO_4 \quad 2H_2O + CO_2$
		(Gypsum)

Flue gas exhausted from the gas/gas heater (GGH) is introduced into the absorber, where dust and SO_2 are removed by the spray liquid. Spray liquid enfused with SO_2 is then oxidized in the lower part of the absorber by injection air.

4) EXPERIENCE WITH IHI LIMESTONE-GYPSUM FGD SYSTEMS

IHI has accumulated much experience with FGD systems, having installed more than 700 units of wet scrubbers since 1962; it also holds the record for number of FGD systems of more than 5,000 MW total capacity supplied to coal-fired thermal power stations. IHI has supplied 11 FGD systems for large-scale coal-fired utility boilers that use the limestone-gypsum process. IHI is one of the leading companies in Japan with regard to FGD systems for coal-fired utility boilers; its market share is about 30% in Japan. All systems installed by IHI have been operated at 100% availability.

IHI has the technologies for FGD and SCR systems as well as boiler plants. It can offer the best integration of systems from front-end to back-end corresponding to current trends in variety of fuel.

As an example of retrofitting coal-fired utility boilers, HSINTA Unit 3 & 4 FGD systems, now under construction in Chinese Taipei, are introduced as one of the latest FGD systems for utility boilers in the APEC region. For industrial use, we introduce a simplified (in-line type) FGD system supplied to the Thai Union Paper Public Co., Ltd.

<u>HSINTA Power Station Unit 3 & 4 FGD system / Taiwan Power Company</u>

IHI was awarded the order for HSINTA Power Station Unit 3&4 FGD systems by Taiwan Power Company on December 1998; delivery is scheduled for November and December 2001 respectively. The outline of HSINTA Unit 3&4 FGD system is shown in Figure 6. Design conditions and features of HSINTA Unit 3&4 FGD system are as follows.

< Design Conditions (per unit) >

- Boiler Type: 550-MW Coal-fired boiler (2 Units)
- Gas Flow Rate: 2,328,450 (m3N/h-wet)
- SO_2 Inlet Concentration: 1,145 (ppm)
- SO_2 Removal Efficiency: 93%
- Gas temperature (inlet): 145 C
- Absorbent: Limestone
- Byproduct: Gypsum

< Features >

- Retrofitted to existing power plant
- Compact design in limited area (the GGH is installed on the top of the absorber).
- FGD arrangement is shown in Figure 7. Layout of Absorption Area is shown in Figure 8. Figure 8 shows that the installation area is reduced by approximately 30% as compared with a conventional arrangement; this was achieved by installing GGH on top of the absorber.

Simple configuration of IHI Spray Tower (shown in Figure 9). The spray tower is the essential equipment in the IHI FGD system, and it has a simple configuration with the following features:

- Easy Scaling-up
- Less Draft Loss
- Clogging Free
- Easy Maintenance

<u>In-line Type FGD system / Thai Union Paper Public Co., Ltd.</u>

This system is one of the demonstration projects for simplified FGD systems under the “Green Aid Plan” of the Japanese Government. The system was inaugurated in 1997 and a demonstration operation was successfully completed in 1998. Since then, a two-year follow-up study has confirmed the system’s operating conditions. The study was supported by the Engineering Advancement Association (ENAA), which was assigned the task by the New Energy and Industrial Technology Development Organization (NEDO).

The process flow and layout of the in-line FGD system developed for Thai Union is shown in Figures 10 and 11. Untreated gas discharged from the boiler passes through the electrostatic precipitator and then flows into the FGD system. Treated gas is returned into the flue gas duct and discharged from the stack. Design conditions and features are as follows.

< Design Conditions >

- Boiler Type: Lignite-fired stoker type
- Steam Generation: 35 ton/hr
- Gas flow rate : 48,000 m^3N/h (wet)
- SO_2 concentration (inlet): 1,200 ppm (dry)
- SO_2 removal efficiency: 70%
- Gas temperature (inlet): 175 C
- Absorbent: Lime mud or limestone (waste from paper production)
- Byproduct: Gypsum

< Features >

- No absorber- spray in the duct
- Smaller installation area– less capital cost
- Simple system– easy operation and lower operating cost

THE SCR PROCESS

The IHI NOx removal plant employs a dry SCR process using ammonia as reducing agent, which is simple yet extremely effective in reducing NOx emissions.

The principle of the SCR process is to decompose nitrogen oxide into nitrogen and water vapor by supplying ammonia into the exhaust gas through the catalyst layer as shown in Figure 12.

$$4NO + 4NH_3 + O_2 = 4N_2 + 6H_2O$$
$$NO + NO_2 + 2NH_3 = 2N_2 + 3H_2O$$

De-NOx reaction occurs at the optimum temperature ranging between 300 and 400 C with a removal efficiency of more than 80%.

THE IHI SCR SYSTEM

The first system was delivered at the end of 1977; 180 systems have now been constructed. Most of the systems are installed in the exhaust gas ducts of utility boilers. The rest are at industrial boilers, heating furnaces and gas turbines.

An installation capable of 180,000 cubic meters of nitrogen per hour (m3N/h) for an oil-fired boiler was commissioned in 1978, followed in 1979 by completion of the world's largest installation, of 1,900,000 m3N/h, for another oil-fired boiler. For coal-fired boilers, an IHI SCR system has been delivered to a 1,050–MW utility unit.

The IHI De-NOx Reactor is shown in Figure 13. IHI standard catalysts contain some active metals with titanium oxide as a carrier in a square lattice honeycomb shape.

Features of the IHI SCR system are as follows:

- Perfect matching with flue gas characteristics (many varieties of catalysts are available for selection);
- Compact design (High performance catalyst);

- Easy operation (Control of ammonia injection is completely automated);
- Stable supply of catalyst (supplied by specialized manufacturers under the guidance of IHI); and,
- Wide application and experience.

CONCLUSION

At present, environmental protection is very important all over the world, and many power stations require retrofitting with FGD and SCR systems. IHI FGD and SCR systems are simple systems with high reliability and efficiency.
IHI can install FGD and SCR systems in limited areas, retrofitting them to existing boilers (as with HSINTA Unit 3&4 for the Thai Union Paper Public Co., Ltd.).
IHI FGD and SCR systems contribute to environmental protection in the APEC region, where remarkable growth of fossil fuel consumption is expected.

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Table 1. SO_x emission in ASIA Region (thousand Ton)

Economy	1975	1980	1985	1986	1987
1. China	10,175	13,372	17,259	1,8326	19,989
2. Japan	2,571	1,604	1,175	1,088	1,143
3. India	1,652	2,010	2,833	2,921	3,074
4. Indonesia	201	329	435	453	485
5. Korea	1,159	1,918	1,366	1,355	1,294
6. North Korea	234	271	324	333	333
7. Chinese Taipei	609	1,036	693	744	605
8. Thailand	224	420	507	528	612
9. Pakistan	148	198	351	345	381
10. Philippines	807	1,041	510	447	370
11. Malaysia	193	272	271	264	263
12. Bangladesh	40	57	46	51	49
13. Vietnam	40	34	38	38	39
14. Hong Kong	109	166	144	149	150
15. Singapore	85	122	147	151	155
16. Nepal	3.7	4.9	7.6	11.33	11.0
17. Myanmar	17.4	30.9	30.0	32.3	29.9
18. Sri Lanka	22.3	30.0	23.5	22.6	28.2
19. Afghanistan	8.1	8.5	8.6	7.5	10.7
20. Mongol	38.7	65.1	89.7	97.0	100.5
21. Brunei	0.4	0.9	1.1	1.0	1.1
22. Cambodia	1.2	1.3	2.8	2.9	2.9
23. Laos	1.3	1.4	1.6	1.7	1.7
24. Maldives			0.3	0.3	0.3
25. Macao	0.9	3.0	6.2	7.1	8.4
Total	**18,340**	**22,997**	**26,997**	**27,377**	**29,136**

Table 2. NO_x emission in ASIA Region (thousand Ton

Economy	1975	1980	1985	1986	1987
1. China	3,727	4,907	6,361	6,772	7,371
2. Japan	2,329	2,132	1,948	1,901	1,935
3. India	1,379	1,623	2,312	2,401	2,556
4. Indonesia	331	465	561	600	639
5. Korea	220	365	464	499	555
6. North Korea	325	383	456	468	468
7. Chinese Taipei	124	225	261	300	325
8. Thailand	182	255	327	341	384
9. Pakistan	101	164	193	201	231
10. Philippines	172	184	173	177	184
11. Malaysia	90	126	167	171	177
12. Bangladesh	46	58	61	65	66
13. Vietnam	120	88	95	98	99
14. Hong Kong	51	67	106	119	134
15. Singapore	43	67	81	84	88
16. Nepal	18	21	34	53	50
17. Myanmar	38	47	50	53	45
18. Sri Lanka	23	31	34	53	37
19. Afghanistan	20	22	24	22	30
20. Mongol	31	49	66	71	72
21. Brunei	2.0	4.0	8.1	7.7	11.1
22. Cambodia	8.6	9.3	11.7	12.1	12.3
23. Laos	7.9	8.0	8.7	8.9	9.1
24. Maldives			0.5	0.6	0.6
25. Macao	2.1	2.9	3.7	4.8	5.0
Total	**9,388**	**11,352**	**13,805**	**14,462**	**15,483**

Figure 1. FGD System installed in Japan

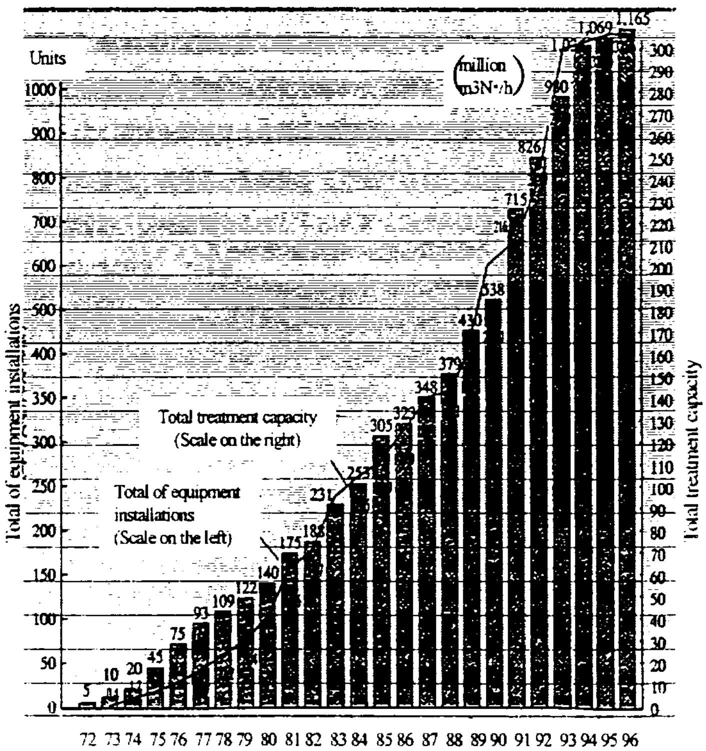

Figure 2. SCR System installed in Japan

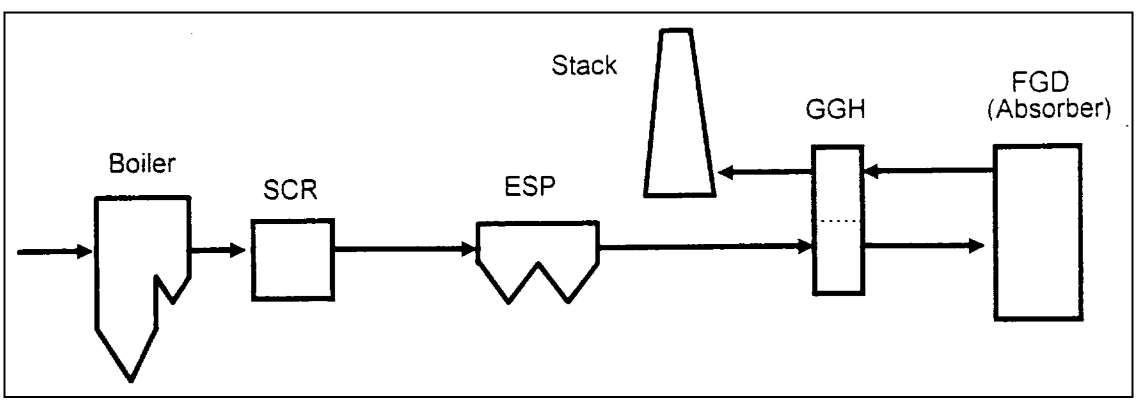

Figure 3. Flue Gas Treatment System

Name of Process	Absorbent	By-Product
Limestone Gypsum	Limestone	Gypsum Cake
Ammonium	Ammonium	Ammonium Sulfate Powder
Magnesium	Magnesium Hydroxide	Magnesium Sulfate Solution
Sodium	Caustic Soda	Sodium Sulfate Powder
Sea Water	Sea Water	—

Table 3. Wet FGD System process

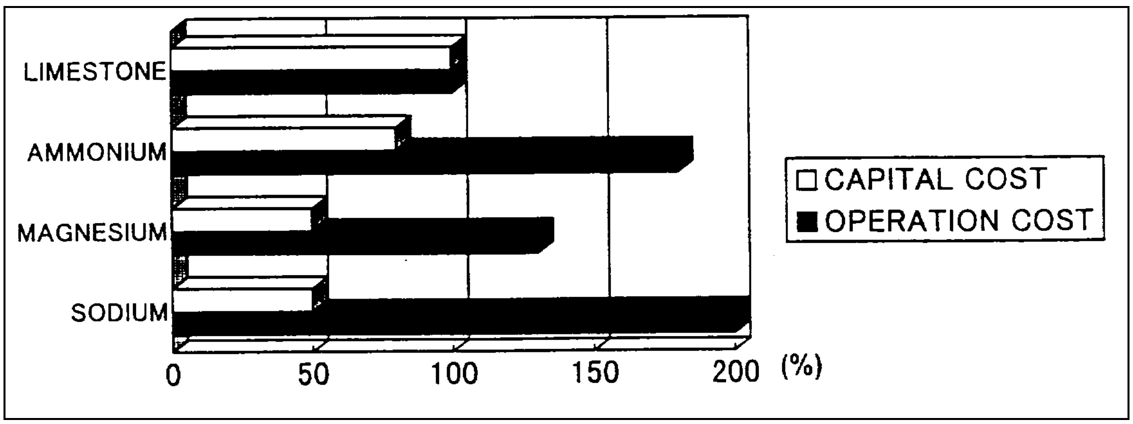

Figure 4. Cost Comparison of Wet FGD processes

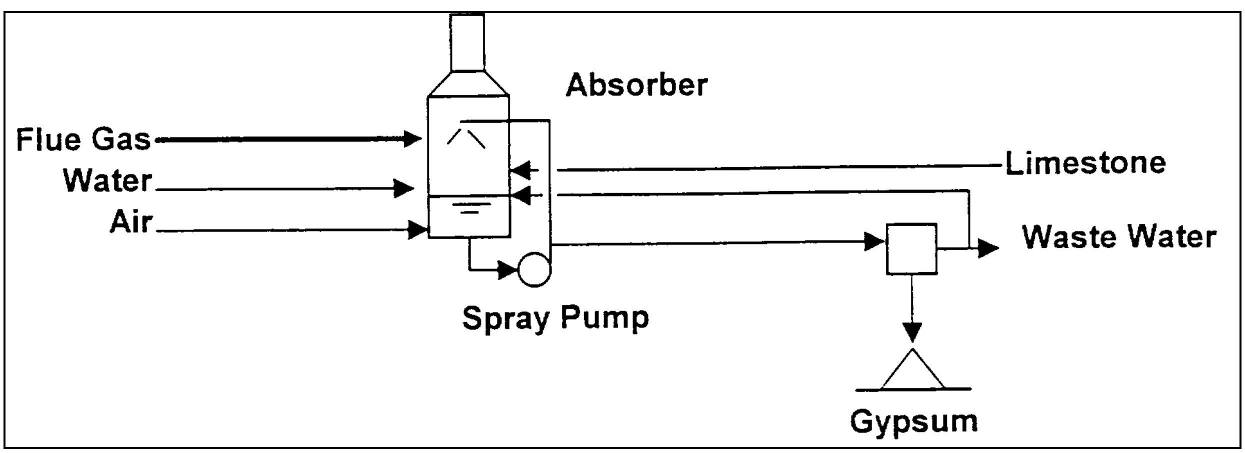

Figure 5. Limestone-Gypsum Process Flow

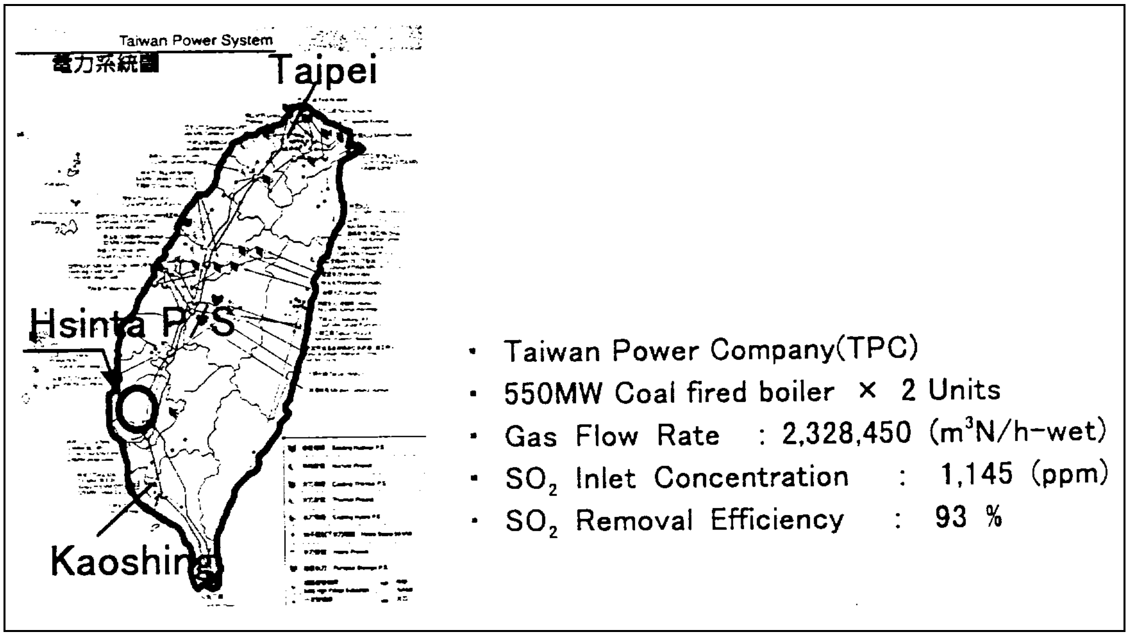

Figure 6. Outline of HSINTA Units 3 & 4 FGD Systems

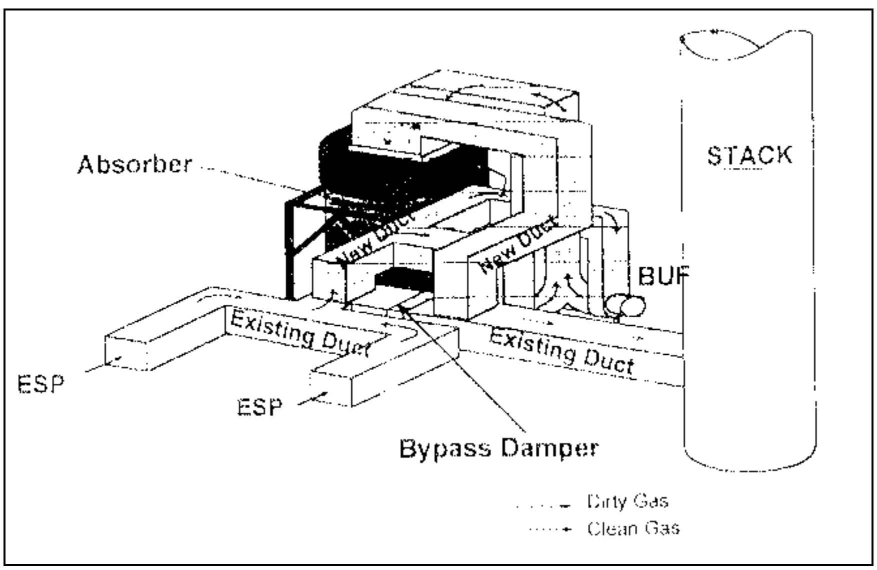

Figure 7. FGD Arrangement of HSINTA Units 3 & 4

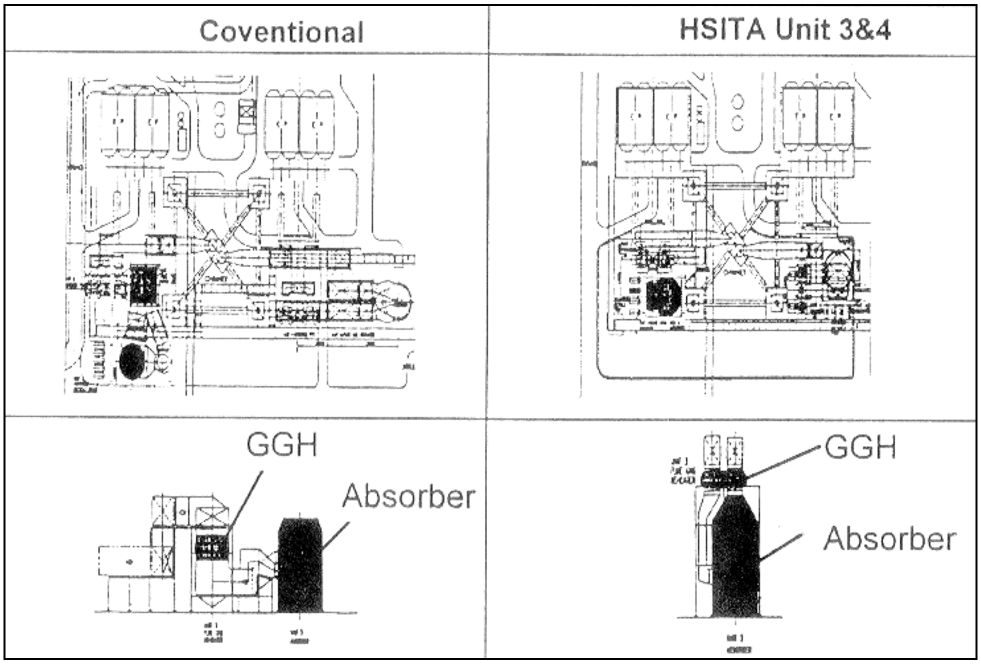

Figure 8. Absorption are layout of HSINTA Units 3 & 4

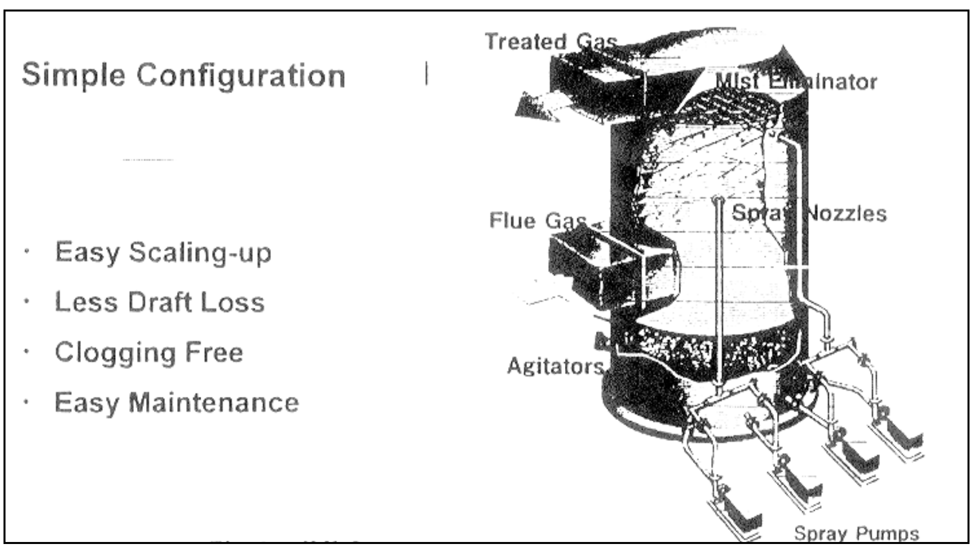

Figure 9. IHI Spray Tower

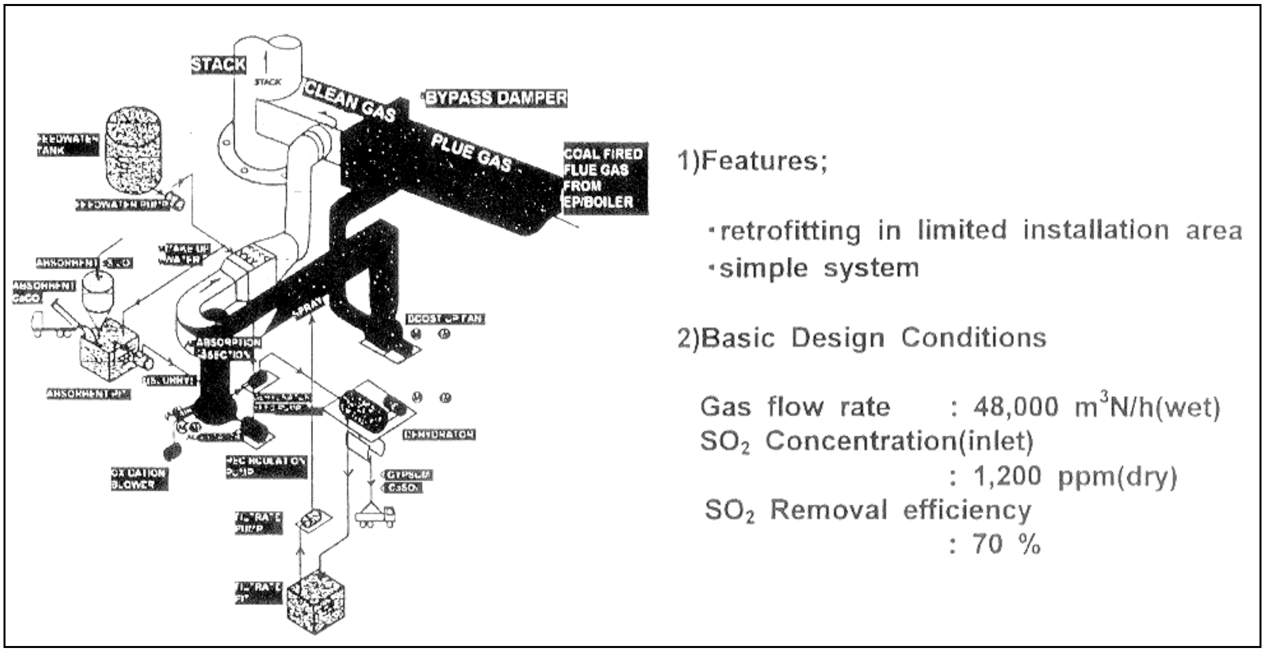

Figure 10. Process Flow of In-line FGD System

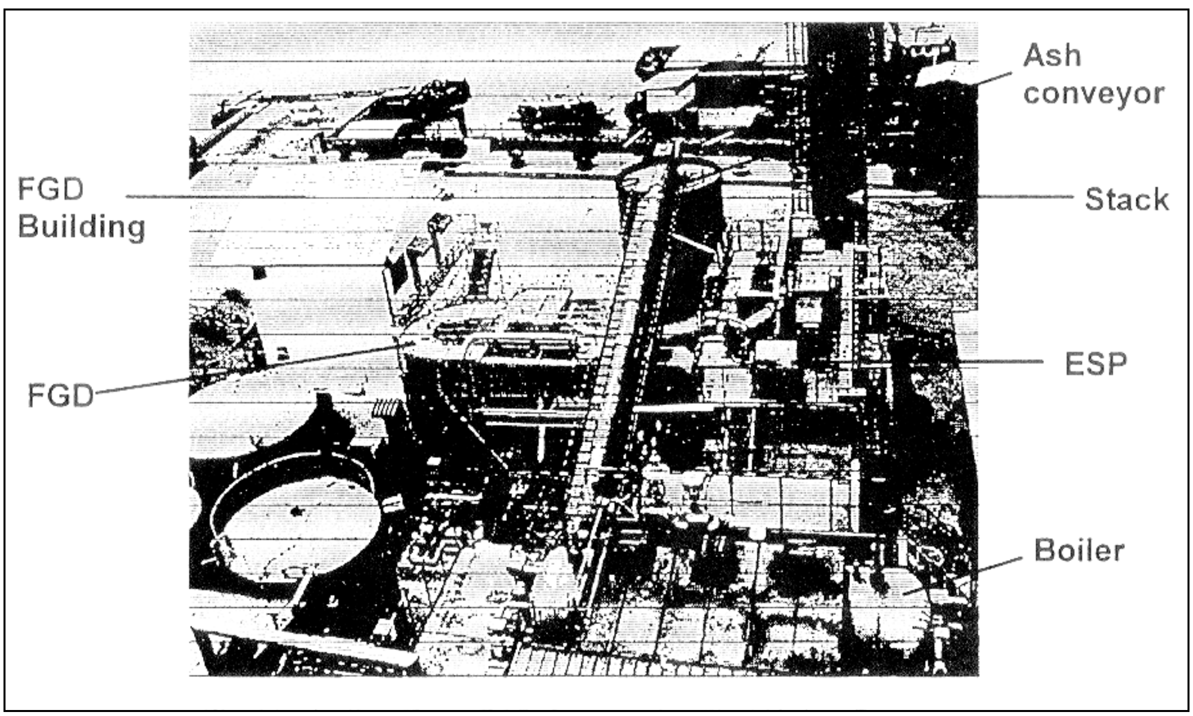

Figure 11. In-line FGD System for Thai Union Paper

	In-line	conventional	condition
Ratio of captal cost per absorption SO_2	50%	100% (base)	Treating gas volume 900,00 m^3N/h SO_2 concentration 2,000 ppm (including installation cost)
Ratio of operation cost per absorption SO_2	70%	100% (base)	

Table 4. Example of economic evaluation

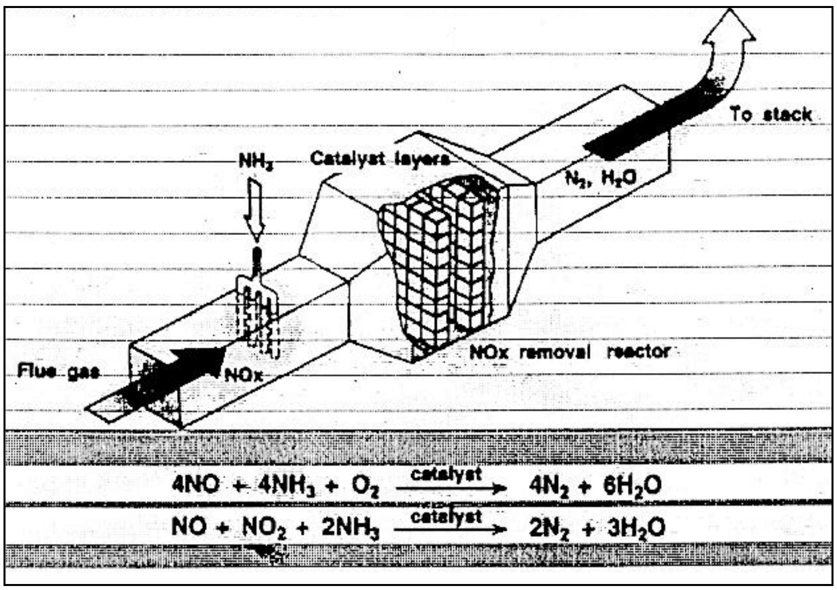

Figure 12. Principle of SCR Process

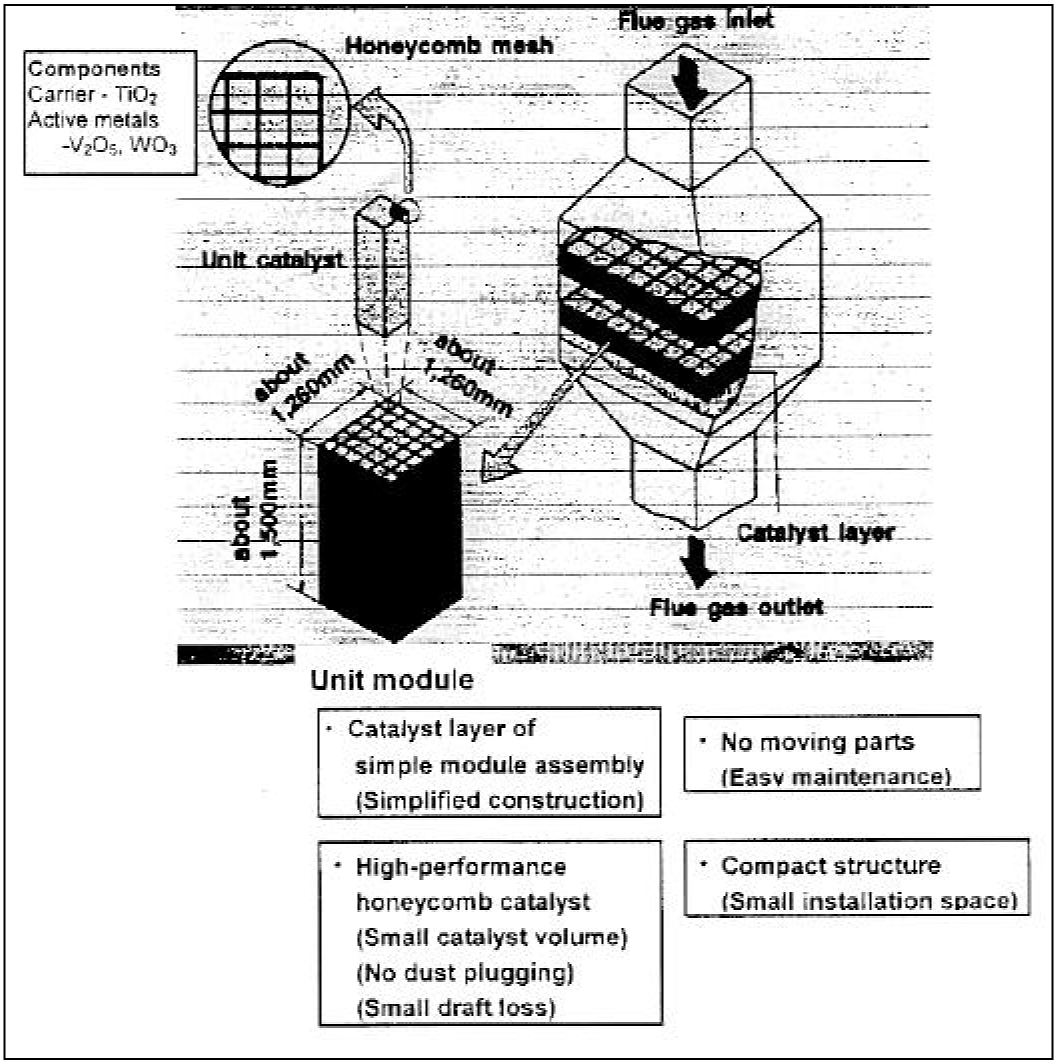

Figure 13. IHI DeNOx Reactor (vertical gas flow)